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ENGINEERING PROLIFERATION AND TEXTURE DURING FRUIT CHIPS VACUUM FRYING

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Abstract– Expansion and development as well as hard and crunchy fried products are characteristics preferred by consumers. To produce the expansion and texture of fried products to suit the tastes of consumers need to control and observe the process conditions and the characteristics of the raw material change during the frying process. During the frying process volume change (expansion and contraction) and changes in texture (hard and crunchy) in foodstuffs. Volume and texture changes thought to be caused by evaporation of water and decreased levels of starch in solids. This research aims to develop a model of changes in volume and texture of the fruit during vacuum frying caused by a decrease in water content and starch content. Samples were jackfruit fried in a vacuum at a temperature of 70 – 100 ^{O}C, old frying pan 15-60 minutes and vacuum pressure 80-90 kPa. Parameters measured were the volume, texture, water content and starch content of samples before and after frying. The results showed that the model developed can be used with either to predict changes in the volume and texture of the product during the frying process in a vacuum.

INTRODUCTION

Frying foods can change the pore structure of the product in the form of shrinkage or expansion. Such changes affect the diffusivity of gas and liquid in the material (Kawas and Moreira, 2000; Lujan and Moreira, 1996; Xiong, Narsimhan and Okos, 1991; Yamsaengsung and Moreira, 2002a). Furthermore Asensio (1999), Yamsaengsung and Moreira (2002b) developed a semi-empirical correlation structure changes in product shrinkage and expansion caused by swelling. The study has revealed changes in volume caused by the loss of bound water and any material changes in the cell structure. However, these studies do not consider the change in volume due to evaporation of water and a decrease in starch content in the material.

Development of mathematical models and structural volume changes during the frying process developed by Kawas and Moreira (1996), Lujan *et. al.,* (1996), Yamsaengsung and Moreira (2002a), Math *et al.,* (2003). Research results explain that frying can cause shrinkage, expansion, density, texture and chemical changes in the material. But not explain changes in volume and texture due to the changing conditions of the raw materials, include: decreased water content and a decrease in starch content. Though this condition is very important to be considered as the cause of the change in volume and texture of the food during frying.

Mathematical models with diverse complexity has been developed. The model relates to frying products based on the condition of the raw material with the assumption of constant physical properties, a large number of models have been based on simple diffusion, heat and mass transfer using a variety of approaches to consider or ignore evaporation (Ateba and Mittal, 1994; Dincer and Yildiz, 1996; Moreira *et al.,* 1995; Rice and Gamble, 1989). However, the model developed, yet showing the relationship of raw materials and frying

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conditions with changes in volume and texture of the product. Though many unwanted changes occur in food during frying process, and these conditions can be minimized if the process is well controlled. Expected with a deeper understanding and assessment to discover the phenomenon of expansion and texture changes during vacuum frying process with raw materials jackfruit, will be possible to do the engineering division and texture in fried products.

Research purposes

This research aims to develop mathematical models and texture changes in the volume of products suspected of fruit chips changes during the frying process in vacuum due to a decrease in water content and starch content in solids.

RESEARCH METHODS

Mathematical model changes in volume and texture

Changes in the volume and texture will determine hardness and crispness of the product. Model changes in volume (V_v) and hardness (T_s) products due to the decrease in water content and a decrease in starch content in solids during the frying process is described in the following equation.

$$V_{v(Ca,\ Cpt)} = aC_a{}^x C_{pt}{}^y \quad .. (1)$$

$$T_{\sigma(Ca,Cpt)} = aC_a^x C_{pt}^y \quad .. (2)$$

The value of a, x and y are evaluated based on data bercobaan with multiple regression least squares method.

Material and Equipment

The main ingredient of research is jackfruit jackfruit bark types (based on the properties of the fruit) is dense flesh, juicy and less aroma. Jackfruit purchased from farmers through fruit traders in traditional markets in New Town Yogyakarta aged 12-24 hours after harvest. It is assumed throughout the solid homogeneous material including solid surface, while supporting materials research is cooking oil and chemicals for chemical analysis.

Samples were fried on a combination of a temperature of 70 to 100 ^{O}C and the old frying pan 15 to 60 minutes and vacuum pressure of 80 to 90 kPa.

The main tool is the vacuum frying (vacuum fryer) made specifically for laboratory scale and designed according to the needs of the research is equipped with a data logger computer systems, while supporting tool is measuring cup, micrometers, analytical balance, moisture analyzer measurement tools and starch content.

TESTING AND ANALYSIS

Measurement of volume. The volume of the sample was measured by using the method of Taiwo and Good (2006). The sample volume is the volume ratio after and before frying. The volume of the sample before and after frying is measured with a measuring cup.

Testing texture. Stress and strain samples was measured using a Universal Testing Machine Do-FBO.STS (Zwich / Zo.5) by way of a sample is placed perpendicular (normal stress) on the foundation suppressor then test equipment is operated.

Analysis of water content. The water content in the sample before and after frying analyzed using vacuum oven method (AOAC, 1970; Snell *et al.*, 1972) with a sample size of 10 g.

Analysis of starch content. The starch content in the samples before and after frying analyzed using method (Direct Acid Hydrolysis Method; AOAC, 1970).

Data analysis. Data were analyzed using multiple regeression and statistics. Regeression multiple methods used to solve systems of linear equations model of changes in volume and texture of the product. While the statistical analysis used multiple regression analysis with SPSS to find significance and influence of moisture reduction and decreased levels of starch to changes in volume and texture.

RESULTS AND DISCUSSION

Jackfruit solids volume changes during vacuum frying

Changes in the volume of solids jackfruit with a variety of oil temperature and vacuum pressure are presented in Figure 1a and 1b. From the images shows the form of depreciation and changes in volume expansion, is affected by temperature and vacuum pressure. The higher the temperature and vacuum pressure there is a tendency solids shrinkage and rapid expansion or otherwise. This was due to the frying temperature and higher

vacuum pressure, heat transfer to the surface and then into the solids faster than the temperature and vacuum pressure is lower, so that water on the surface and inside the solid faster out cause solids into shrinking and some time into bloom. Depreciation continues before evaporation of free water is not constant or when the water level is still above 15%, the situation is not the creation, but some time after the moisture content below 15% solids has begun to swell and eventually into bloom.

Shrinkage and expansion suspected relationship with the evaporation of free water in solids, so that evaporation of free water causes solids shrinkage and expansion. These results are consistent with research Asensio (1999) and Yamsaengsung and Moreira (2002a) who explains that the material changes during frying due to the loss of bound water in the material. At the beginning of the frying pan first free water on the surface of the water out and some free time in solids also out resulting solid is shrinking. After all the free water out hardening on the surface so that most of the free water trapped within the solids. Because receive hot water, so that it becomes steam (expansion) solids eventually become fluffy.

Jackfruit solid texture changes during vacuum frying

Violent change research results with a variety of solids jackfruit oil temperature and vacuum pressure are presented in Figure 2a and 2b. Based on changes in hardness profile images appear influenced by temperature and pressure vacuum. The higher the temperature and vacuum pressure solids seems there is a tendency to change fairly high hardness value or vice versa. This was due to the frying temperature and higher vacuum pressure, heat transfer to the surface and then into the solids faster than the temperature and vacuum pressure is lower, so that water on the surface and inside the solid faster out cause solids into shrinking and some time into bloom. In addition, changes in connection with the suspected violent evaporation of free water in solids.

At the beginning of the frying pan first free water on the surface of the water out and some free time in solids also out resulting solid is shrinking. After most of the free water out so that the surface hardening portion of free water is still trapped in the solid lead jackfruit chips texture properties change the original software eventually becomes hard. Point the rate of change of the soft texture becomes hard if it appears occurs during evaporation of free water is not constant or moisture in solids above 15%, but some time after the evaporation of free water has been constant or moisture content below 15% increase in product hardness higher up the end of the frying pan. The results are consistent with research Yamsaengsung and Moreira (2002a) who found a relationship changes due to decreased levels of water hardness with the formation of a hard layer on the surface and pore development in the tortilla chips.

Jackfruit solids moisture reduction during vacuum frying

Jackfruit solids moisture reduction during frying oil at various temperatures and vacuum pressure are presented in Figure 3a and 3b. From the images appear free water evaporation rate during frying

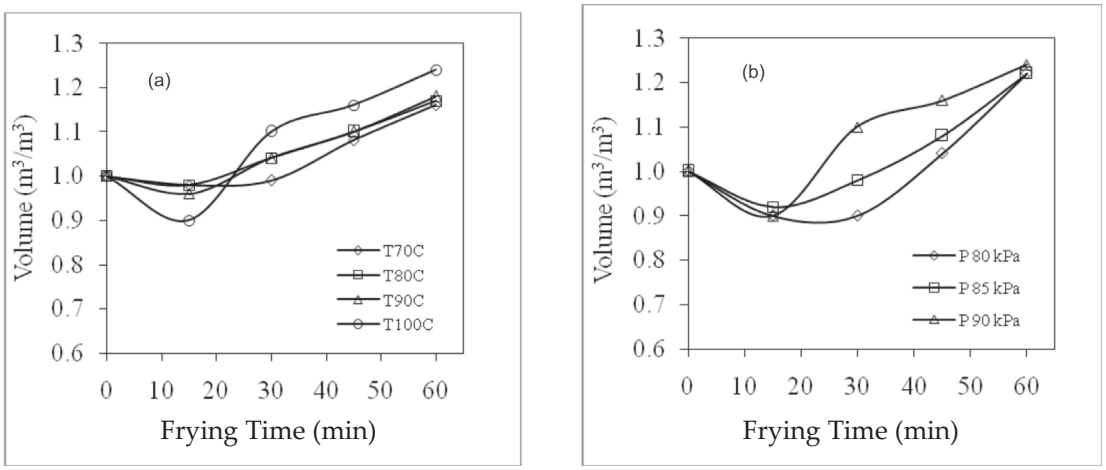

Fig. 1. Changes in the volume of solids jackfruit during frying (a) the temperature variation in the vacuum pressure of 90 kPa and (b) vacuum pressure variation in oil temperature of 100 ^{O}C

presumably also influenced by temperature and pressure vacuum. The higher the temperature and vacuum pressure there is a tendency of free water evaporation rate sooner or vice versa. This is because the boiling point of water and the evaporation of water is influenced by vacuum pressure. This study supports the research Garayo and Moreira (2002), which explains that the potatoes are fried at a higher temperature with the same vacuum pressure requires less time to reach the same moisture content. At the beginning of the frying pan evaporation of free water appears nearly constant solids before the water level reaches 15%, some time later slowed and became constant after moisture content below 15%.

Moisture reduction is presumably no relation with changes in volume and texture solids. Point change in volume and texture, where the solids begin to shrink and shrink pores starting from the beginning of the frying pan to the evaporation of free water is not constant when the moisture content above 15%, but some time after the evaporation of free water is constant when the moisture content below 15%, solids began to swell back and pore enlargement to be a bloom. These results are consistent with research Kawas (2002) and Yamsaengsung and Moreira (2002a) who explains that the evaporation of water from the solids cause shrinkage and after all the bound water evaporates, tortilla chips into bloom because of the pressure of the gas in totilla chip.

Decreased levels of starch solids jackfruit during vacuum frying

The decrease in the starch content of solids during frying in oil temperature variations are presented in Figure 4a and 4b. From these images appear to decrease the rate of starch content seems the same as the rate of decline in water levels in solids. The turning point seems to be influenced by temperature and vacuum pressure, the higher the temperature and vacuum pressure the more starch in solids decreased or conversely the lower the temperature and vacuum pressure the less starch decreased. From the beginning of the frying already underway decreased levels of starch in solids. Decreased levels of starch in the solid granules are thought to be caused inflate the greater due to increasing frying time and temperature rise. This condition causes the amylose molecules separated out and out of the granules, so the longer the time, and high-temperature frying, diminishing levels of starch in solids.

Decreased levels of starch in the solid granules are thought to be caused inflate the greater due to increasing frying time and temperature rise. This condition causes the amylose molecules separated out and out of the granules, so the longer the time, and high-temperature frying, diminishing levels of starch in solids. These results are consistent with research Juliastuti and Dian, (2009) describes the starch content in the solids decreased due to the heating process of starch will undergo gelatinization process whereby starch granules swell, with enlargement of the starch granules will weaken the hydrogen bonds, thus amylase enzyme will facilitate penetration to decide glucoside bond in starch and ultimately change starch into glucose. Another possibility is causing the starch in jackfruit solids reduced because of increased levels of oil

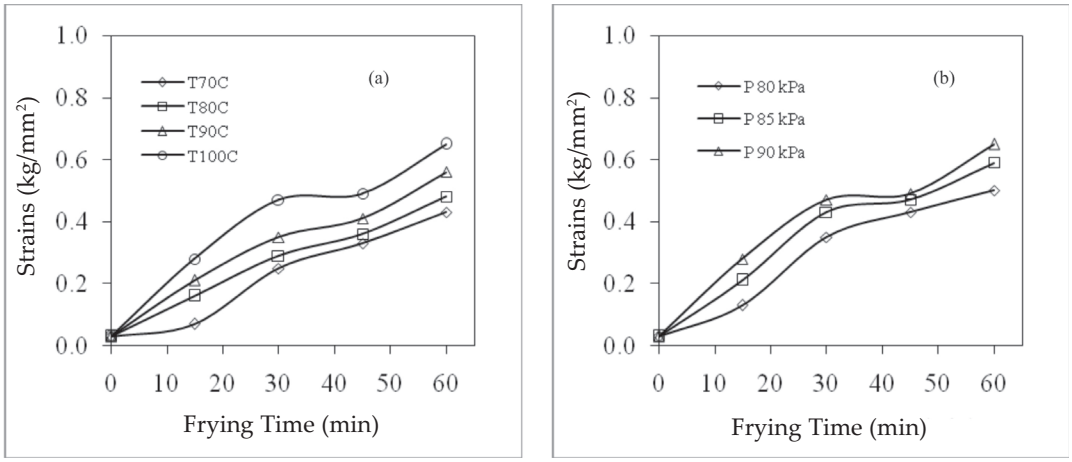

Fig. 2. Changes in texture solids jackfruit during the frying process (a) the temperature variation in the vacuum pressure of 90 kPa and (b) vacuum pressure variation in oil temperature of 100 ^{O}C

occurring siqnifikan with temperature and vacuum pressure. Similarly, the decrease in water content. Decreased levels of starch seems to be of relevance to the changing volume and porosity solids. The incorporation rate of change of volume and texture, due to the evaporation of water and decreased levels of starch will be able to demonstrate the relationship these three processes.

Changes in the division as a function of water evaporation and decreased levels of starch solids jackfruit during vacuum frying

The incorporation rate of change of volume, decreased water content and a decrease in starch content in solids during frying at 100 ^{O}C with a vacuum pressure of 90 kPa is shown in Figure 5a. Interconnectedness of the images appear three processes, namely the change in volume, a decrease in water levels and decreased levels of starch during frying under vacuum. Changes in volume starting from the initial volume then turned into shrinking rapidly, after some time the volume back into bloom. Depreciation allegedly caused by the evaporation of free water from the solids which occur due to the pressure difference inside and on the surface of solids. Because the pressure in solids higher when compared to the outside, the water in the solids out. By the time the water level is still above 15% depreciation continued to take place and solids do not undergo division.

Expansion began to occur when the water content below 15% by the time the pressure in the solids were nearing the pressure at the surface, the heat causes the hardening on the surface slowly, so most of the water will be trapped in the solid. Water vapor trapped in solids do not come out again and be pressurized and form pockets of gas, causing the solids into expands and eventually into bloom.

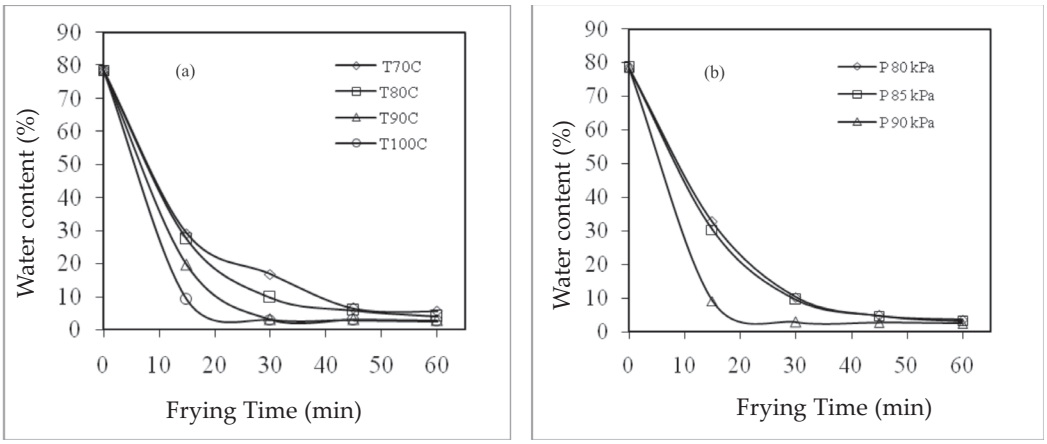

Fig. 3. Decrease the water content of solids jackfruit during frying (a) the temperature variation in the vacuum pressure of 90 kPa and (b) vacuum pressure variation in oil temperature of 100 ^{O}C

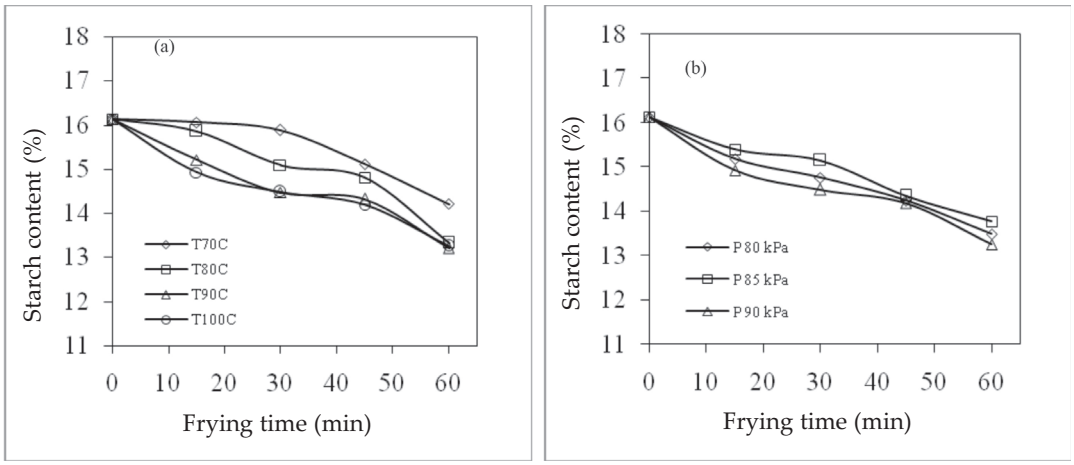

Fig. 4. Decreased levels of starch solids jackfruit during frying (a) the temperature variation in the vacuum pressure of 90 kPa and (b) vacuum pressure variation in oil temperature of 100 ^{O}C

Similarly, changes in starch content. Changes in starch content seem to have anything to do with the change in the volume of solids. At the point where drastic changes in starch content of starch that is currently in the top 15%, solids shrinkage and not inflate. But once past that point or at the time of the starch content below 15%, which is almost unchanged again starch solids have started to swell and eventually into bloom.

Calculation of volume change, water evaporation and decreased levels of starch in solids during frying by equation (1) solved by multiple regeression using a computer program are presented in Figure 5b. Mathematical models jackfruit solids volume changes caused by the evaporation of free water and a decrease in starch content during vacuum frying process expressed in equation (3) below.

$$V_v = 133{,}98\, C_a^{\,0.03}\, C_{pt}^{\,-1.82} \qquad (3)$$

Statistical analysis showed a decrease in water content and starch content significantly affect the change in the volume of solids ($p < 0.01$), either individually or jointly. Individually contribute to a decrease in the water content of 31% of volume change is smaller when compared to the decrease in starch content which contributed 60.1% of volume change, while simultaneously a decrease in water content and starch content contributed 60.1% to the volume change solids.

CONCLUSION

The conclusion that can be drawn from these results is that the temperature and pressure vacuum effect on the changes in volume and changes in texture and water evaporation and decreased levels of starch in solids during frying. The rate of change of volume and texture influenced by the rate of evaporation of water and the rate of decrease in starch content. If free water evaporation is not constant when the water level is still above 15%, occurred shrinkage and reduction of violence, some time after the evaporation of free water constant or moisture content below 15% began the creation and improvement of violence until the end of the frying pan. Similarly, the rate of decrease in starch content, the rate of change of volume and texture appear to occur to a decrease in starch content is not constant or above 15%. But after nearly constant or starch content below 15% began the creation and hardening solids. Developed a mathematical model that can be used with either to predict changes in volume and texture due to water evaporation and decreased levels of starch products during the frying process in a vacuum.

List of Symbols

a	Constants	-
C	Concentration	kg/m^3 total
V	Change	-
T	Change	
x, y	Exponent	-
Subscripts		
a	The water in the solids	-
pt	Starch in solids	-
v	Volume	m^3
s	Tension	Kg/mm^2

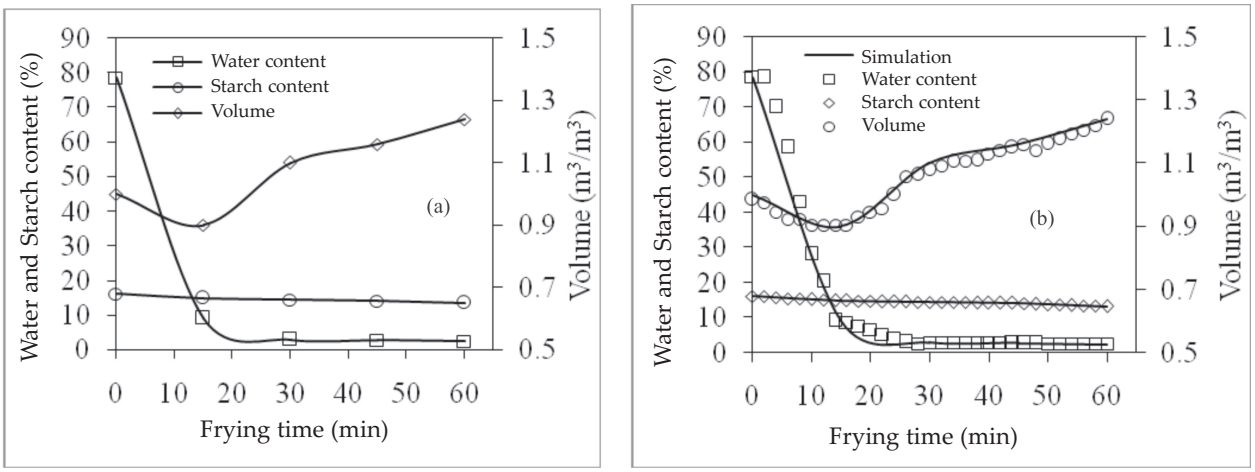

Fig. 5. Expansion, reduction of water levels and decreased levels of starch solids jackfruit during frying oil at a temperature of 100 ^{O}C with a vacuum pressure of 90 kPa (a) observational data and (b) the results of simulation models.

REFERENCES

AOAC, 1970. *Official methods analysis of the associations of official analutical chemists*. Association of Afficial Analitycal Chemists, Washington, DC.

Asensio, M. C. 1999. *Transport phenomena during drying of deformable, hygroscopic porous media*: *Fundamentals and applications*. Ph.D. dissertation, Texas A&M University, College Station, TX.

Atteba, P., dan G.S. Mittal, 1994. Modeling the deep-fat frying of beef meatballs. *International Journal of Food Science and Technology.* 29 : 429-440.

Dincer dan Yildiz, 1996. Modeling of thermal and moisture diffusions in cylindrically shaped sausages during frying. *Journal of Food Engineering.* 28 : 35–43.

Edwards, A. L. 1976. An Introduction to linier regressiaon on correlation for India. National Seed Corporation. New Delhi.

Firdaus, M., Bambang, D. A. and dan Harijono, 2001. Absorption of oil on French fries potatoes. *Biosain.* 1(2) : 76-85.

Garayo, J. and dan R, Moriera, 2002. Vacuum fraying of potato chips. *Journal of Food Engineerin.* 55 : 181–191.

Juliastuti, S. R. and dan Y. P. Dian, 2009. Reaction kinetics parameters alpha-amylase and glucoamylase on the yield of glucose from the hydrolysis process solid waste tapioca. *National Seminar on Chemical Engineering Indonesia.* Bandung, 19-20 Oktober 2009.

Kawas, M. L. and dan R.G. Moreira, 1996. Characterization of product quality attributes of tortilla chips during the frying process. *Journal of Food Engineering.* 47 : 97–107.

Kawas, M. L. and dan R. G. Moreire, 2000. *Characterization of product quality attributes of tortilla chips during the frying process*. M.S. thesis, Texas A&M University, College Station, TX.

Lujan F.J., Acosta dan R.G. Moreira, 1996. Relationship between tortilla chips microstructure and oil reduction. *Cereal Chemistry Journal.* 74 : 216–223.

Math, R. G., Velu, V., Nagender, A. and dan D. G. Rao, 2003. Effect of frying conditions on moisture, fat and density of papad. *Journal of Food Engineering*. 64 : 429-434.

Moreira, R.G., J.E. Palau dan X. Sun, 1995a. Deep-fat frying of tortilla chips: An engineering approach. *Food Technology*. 49 : 146–150.

Rice, P., dan M.H., Gamble, 1989. Technical note: modeling moisture loss during potato slice frying. *International Journal of Food Science and Technology*. 24 : 183–187.

Supriyanto, 2007. The process of frying food sources of starch: amylose-amylopectin ratio study. Disertasi. Sekolah Pascasarjana. UGM Yogyakarta.

Shyu, S., Hau, L. and dan Hwang, L. S. 1998. Effect of vacuum frying on the oxidative stability of oils. *Journal of American Oil Chemical Society.* 75 : 1393-1398.

Taiwo, K. A. and dan O. D., Baik, 2006. Effects of pre-treatments on the shrinkage and textural proper-ties of fried sweet potatoes. LWT 40 : 661-668.

Whitaker, S. 1977. Simultaneous heat, mass and momentum transfer in porous media: A theory of drying. *Advances in Heat Transfer.* 13 : 119–203.

Xiong, X., Narsimhan, G. dan and Okos, M. R. 1991. Effect of composition and pore structure on binding energy and effective diffusivity of moisture in porous food. *Journal of Food Engineering*. 15 : 187–208.

Yamsaengsung dan Moriera, 2002a. Modeling the transport phenomena and structural changes during deep fat frying. Part I: Model development. *Journal of Food Engineering* 53 : pp. 1–10.

Yamsaengsung dan Moriera, 2002b. Modeling the transport phenomena and structural changes during deep fat frying. Part II: Model solution and validation. *Journal of Food Engineering* 53: 11–25.